

ARCHIDIUM CRASSICOSTATUM (ARCHIDIACEAE), A NEW AND LONG-OVERLOOKED SPECIES FROM CALIFORNIA, U.S.A.

DAVID R. TOREN, KENNETH M. KELLMAN, AND JAMES R. SHEVOCK¹

California Academy of Sciences, Department of Botany, 55 Music Concourse Dr., Golden Gate Park, San Francisco, CA 94118-4503

¹jshevock@calacademy.org

ABSTRACT

Archidium crassicostatum D.R. Toren, Kellman & Shevock is described and illustrated, and is currently known from two counties from California. It appears to be the sole species of the genus from the state and is well marked by its exceptionally wide costa, which can occupy as much as one-third the width of the leaf base. Previous reports of *Archidium alternifolium* (Dicks. ex Hedw.) Schimp. and *A. donnellii* Austin from California are actually *A. crassicostatum*. Details of habitat, ecology, and distribution are given and morphological distinctions among similar-looking but unrelated taxa are discussed.

Key Words: bryophytes, California Floristic Province, cleistocarpous mosses, Mediterranean climate, taxonomy.

The Archidiaceae are a monotypic family comprising about 30 species (Stone 2006) and a majority of these are found only south of the Tropic of Cancer (Snider 1975). *Archidium* Brid. is most abundant in Australia with 16 species (Stone 2006), Africa has 14 species (Magill 1981), Chile has two species (Müller 2009), and one species occurs on the Iberian Peninsula (Guerra and Brugués 2015). In North America, six species are known, but the genus is notably absent from the western part of the continent (Snider 1975).

Several species of the genus are poorly known. For example, in his worldwide monograph, Snider (1975) recognized 26 species, and at that time, 12 of these were known from three collections or less, and six species were known from less than ten collections each. Considering that a substantial number of species of the genus inhabit Mediterranean-type climate areas in Australia (Stone 2006), Chile (Müller 2009), South Africa (Magill 1981), and the Iberian Peninsula (Guerra and Brugués 2015), it is noteworthy that the genus was only recently detected in California, well known for its similar climate (Burge et al. 2016). Some explanations for this might be that the plants are very small, inconspicuous, and have a drab aspect. Also, most shoots in a colony lack sporophytes, and even when present they are difficult to see. Thus, *Archidium* may have been passed over as something unidentifiable and unworthy of collection.

The first verified California report of *Archidium* is from Santa Cruz County, identified as *A. alternifolium* (Dicks. ex Hedw.) Schimp. (Kellman 2003). Subsequently, the second author collected plants from this county in 2004. These collections formed the basis for the reference of *Archidium* in the state (Norris and Shevock 2004; Spence 2007; Malcolm et al. 2009; Burge et al. 2016). The genus was first discovered in Lake County, California in 2011 by the

first author and Ed Dearing. These plants were initially determined as *A. donnellii* Austin, but with reservations regarding a number of morphological characters. Later, in 2015 two additional localities were reported from Lake County as *Archidium* sp. (Toren 2015). In the spring of 2016, plants were re-collected from one locality in each of the above mentioned counties and this revealed that both populations were larger than previously thought.

In 2015, *Archidium* specimens from California were sent to William Buck at the New York Botanical Garden, who suggested the plants might be undescribed. Upon critical examination of more abundant material, we conclude these specimens do not conform to *A. alternifolium*, *A. donnellii*, or any other species treated in the worldwide monograph of *Archidium* (Snider 1975), or in the regional floras for the genus in Australia (Stone 2006), North America (Spence 2007), South Africa (Magill 1981), and Mexico (Sharp et al. 1994). A few additional species of *Archidium* have been described more recently, including *A. yunnanense* Arts & Magill (1994) from China and *A. oblongifolium* D. F. Peralta, A. B. M. Rios & B. Goffinet (2015) from Brazil. However, these species are morphologically very different from the Californian plants and appear to belong to other sections of the genus as defined by Snider (1975).

TAXONOMIC TREATMENT

Archidium crassicostatum D.R. Toren, Kellman & Shevock sp. nov. (Fig. 1).—TYPE: USA, California, Lake Co., Robin Hill near north shore of Clear Lake and south of Rodman Slough County Park, T15N, R9W, section 31, 39°06'30.1"N, 122°53'46.7"W 1350 ft., 1 May 2016, Toren & Dearing 10400 (holotype: CAS; isotypes CONN, MO, NY).



FIG. 1. *Archidium crassicostatum* D.R. Toren, Kellman & Shevock. 1. Two fertile habits. 2. Three sterile habits. 3. Dissection showing capsule foot. 4. Opened capsule with spores. 5. Two perichaetial leaves. 6. Four cauline leaves. 7. Four basal leaves. 8. Apex of perichaetial leaf. 9. Apex of cauline leaf. 10. Basal leaf cells. 11. Sections through medial cauline leaves, base to apex. 12. Basal cells of perichaetial leaf. 13. Stem cross section. Scale bars: 1 mm, habits: 1–3; 150 µm, spores: 4; 0.25 mm, leaves: 5–7; 50 µm, cells: 8–13. All from *Toren & Dearing 10400*.

Diagnosis: The Californian plants can be differentiated from all members of *Archidium* by the plane, channeled leaves, the areolation of small, quadrate, thick-walled cells in many rows at the base of the vegetative leaves and strong costa which is broader than any other species of the genus.

Plants small, perennial by continuous production of branches, 3–5 mm high, green to yellow-green to dingy yellow-brown to tan, gregarious to loosely caespitose, when well developed forming turfs with the shoots occasionally becoming procumbent. **Stems** of the current season ± evenly foliate, simple to 2–3-branched, erect to stoloniferous, 1–2 sterile inno-

tions often produced in axils of perichaetial leaves. Stem cross section rounded, central strand present, inner cortical cells large, with thickened yellowish walls, outer cortical cells smaller and darker in color. **Rhizoids** smooth, pale grayish brown. Lower stem including buried portions dark brown to blackish, with chlorophyllous regenerative shoots having much reduced leaves. Lower stem leaves near soil level small, bract-like. **Upper stem leaves** when dry erect-patent with upper parts $\pm$ incurved, flexuose to erect and appressed, slightly spreading when wet, varying from deltoid-ovate to oblong-lanceolate to lanceolate, shortly to gradually acuminate, channeled, tubulose in upper one-fifth of leaf, 0.8–1.1 mm long, 0.3–0.4 mm wide, margins entire, plane. **Costa** 75–140 μm , somewhat broader at base, filling one-third of width of leaf, in cross section flattened to crescent-shaped, with adaxial cells only somewhat differentiated from the abaxial cells, stereids and differentiated guide cells absent, filling the acumen to shortly excurrent in a stout spine. Areolation $\pm$ uniform, cells firm-walled, $\pm$ thickened, yellowish. **Median and upper cells** mostly quadrate to occasionally short rectangular, $7.5(-10.0) \times 7.5(-17.0)$ μm , somewhat bulging in cross section, sometimes bistratose in 1–2 rows juxtacostally. **Basal cells** quadrate in 12–16 rows from costa to margin, $7.5(-10.0) \times 7.5(-10.0)$ μm . Alar cells not differentiated. Specialized asexual reproduction absent. Sexuality unconfirmed, perigonial buds and antheridia not seen. **Perichaetial leaves** erect to erect-spreading, concave, mostly broadly ovate or elliptic, acuminate, somewhat larger than stem leaves, sheathing the capsule, entire, not recurved; costa (125–)175–200 μm wide, excurrent in a stout spine; leaf cells in lower one-third of leaf hyaline with age, thin walled, rectangular, mostly 3:1 (6:1), cells in upper part of leaf firm-walled, irregular in shape, mostly 2:1. **Vaginula** spherical when young, becoming cup-shaped with an embedded bulbous foot. **Sporophytes** rare, 1 per stem, capsule globose, 350–550 μm in diameter, attached to foot, yellow with scattered black spots, seta none, exothecial cells irregular in shape, thin walled, stomata absent. **Spores** about 30 per capsule, spherical to $\pm$ polyhedral, hyaline to pale yellow, smooth to finely granulose, 150–160 μm in greatest dimension.

Paratypes: USA, CALIFORNIA, **Lake Co.**: Hidden Valley at end of Conestoga Road, 1400 ft., 11 February 2013, *Toren & Dearing 9994* (CAS); north shore of Clear Lake, Robin Hill south of Rodman Slough County Park, 1350 ft., 18 March 2015, *Toren 10328* (CAS), and 10 May 2015, *Toren & Dearing 10338, 10339* (CAS); meadow northwest of Boggs Lake, 2800 ft., 11 May 2015, *Toren & Dearing 10351* (CAS); northwest of Rodman Slough, inlet to Clear Lake upslope from road curve, 1340 ft., 1 May 2016, *Toren & Dearing 10405* (CAS); **Santa Cruz Co.**: Wilder Ranch State Park, off Englesman Loop Trail, 140 m, 6 March 2004, *Kellman 3531* (CAS) and same locality, 27 Mar 2016, *Kellman 8101* (CAS, CONN).

TAXONOMIC RELATIONSHIPS

According to Snider (1975), *Archidium* consists of four sections, based on various combinations of morphological characters which illustrate the principal divergent trends within the genus. Following this systematic concept, *A. crassicostatum* seems to belong in section *Phascoidea* G. Roth., which is defined by irregular areolation in the perichaetial leaves, thick-walled cells of the stem and innovation leaves, poorly differentiated alar cells, and as an apparent adaptation to drier habitats, julaceous to erect spreading leaves.

The new species is further characterized by a number of microscopic features, but since the plants are often encrusted or infiltrated with algae and soil particles, they should first be cleaned in hot water. When leaves are stripped from the stem and mounted, a large patch of stem cortical cells remains attached to the costa base (Fig. 1.10). This character also occurs in *A. elatum* Dixon & Sainsbury of Australia and New Zealand. Another microscopic feature is that the leaf basal cells, especially those of the costa, contain numerous, scattered, yellowish oil droplets.

ETYMOLOGY

The name of the species derived from the Latin refers to the remarkably stout, broad costa.

HABITAT AND ECOLOGY

Archidium crassicostatum is found in bare, sandy soil in sheet drainage areas, seasonally moist meadows, hillside seepages and trail banks mostly in clearings in chaparral and oak woodlands up to the Yellow Pine Forest. (500 to ca. 2800 ft.). The species is tolerant of extended hot and dry periods during the summer season. It seems to prefer moderately disturbed areas where native and non-native vegetation, especially grasses, have not completely invaded. Older stems within colonies sometimes become prostrate and buried, especially on sandy soils. Later, new shoots often arise from the leaf axils of moribund shoots (Fig. 1.2). Stone (2006) noted that several species of *Archidium* are efficient soil binders since the plants spread by repeated seasonal growth increments of fertile and sterile branches accompanied by abundant rhizoids. This phenomenon was observed on a small scale at the type locality of *A. crassicostatum*. Fruiting plants of the new species are generally rare in all populations and the capsules are very inconspicuous because they are mostly overtopped by surrounding innovation and perichaetial leaves (Fig. 1). Mosses often associated include *Bartramia aprica* Müll. Hal., *Ceratodon purpureus* (Hedw.) Brid., *Entosthodon californicus* (Sull. & Lesq.) H. A. Crum & L. E. Anderson, *Ephemerum serratum* (Schrad. ex Hedw.) Hampe, *Pleuridium acuminatum* Lindb., and *Tim-*

miella anomala (Bruch & Schimp.) Limpr. The liverworts *Cephaloziella divaricata* (Sm.) Schiffn., *Riccia campbelliana* M. Howe, and *R. trichocarpa* M. Howe occur in smaller quantities. Some associated vascular plants are *Arctostaphylos manzanita* Parry, *Baccharis pilularis* DC., *Eriogonum fasciculatum* Benth., *Eryngium* sp., *Juncus capitatus* Weigel., and introduced grasses.

DISTRIBUTION

Based on current data, *A. crassicosatum* is endemic to California and restricted to the Coast Ranges in Lake and Santa Cruz counties. It is highly probable the new species will be found in the intervening counties and additional searching in the California Floristic Province may reveal more localities, furthering a better understanding of its geographical distribution. Although it is a perennial moss, it is small and therefore more easily seen during the spring.

MORPHOLOGICAL DISTINCTIONS AMONG SIMILAR APPEARING TAXA

Fertile *Archidium crassicosatum* can be recognized immediately by the immersed, hidden spherical capsule with very large spores, in combination with the plane lanceolate leaves and broad costa. However, sterile plants could easily cause confusion. Comparison must be made with mosses with immersed capsules including *Acaulon* Müll. Hal., *Phascum cuspidatum* Hedw., *Ephemerum* spp., *Micromitrium* spp., and *Pleuridium* spp. Fortunately, all of these mosses produce capsules frequently. *Phascum cuspidatum* is easily separated based on its much broader leaves and papillose leaf cells. *Ephemerum* Hampe and *Micromitrium* Austin are much smaller plants whose capsules are almost always present and exposed. Furthermore, both have spores that are less than 120 µm. An apiculate capsule and persistent protonema further distinguish *Ephemerum* although its sporophyte is also hidden by the leaves, *Acaulon* is a bulbiform plant without the extended stem system of *Archidium*, and its spores are less than 50 µm. When capsules are present, *Pleuridium* Rabenh. is also easy to separate, since its capsules are exposed, ovoid with an apiculate tip and its spores are less than 50 µm. Without capsules, the two can be quite similar. Although they can share bistratose juxtacostal cells, the leaves of *Pleuridium* spp. are usually more subulate than *Archidium crassicosatum* and they have a distinct stereid band in the costa.

Because the distinct sporophyte is not easily seen in the field, *Archidium crassicosatum* somewhat resembles sterile forms of *Ceratodon purpureus* and a few species of *Didymodon* Hedw. and *Pseudocrossidium* R.S. Williams. All of these have exerted sporophytes, so fertile forms deserve no further mention. Sterile *Didymodon* can be immediately ruled out with the recurved leaf margins. Although

the papillosity of *Didymodon* is often indistinct, it can always be detected at least on lateral view of the leaf margins. The revolute margins of *Pseudocrossidium* can be seen in the field if the leaves are wet, but when dry confusion is possible. A cross section of the leaf of *Pseudocrossidium* also reveals a strong stereid band.

The very plastic *Ceratodon purpureus* presents the largest challenge both macroscopically and microscopically. Usually, *C. purpureus* has recurved margins, which are irregularly serrulate near the apex. This normal form provides no difficulty in separation. However Burley and Pritchard (1990) allow for rarely entire and plane margins in their definition of the species. In this form, one must resort to a leaf cross section to see the stereid bands in the costa.

Separation from other species within *Archidium* nearly always requires sporophytes and perichaetial leaves. Snider (1975) emphasizes the position of the gametangia as a taxonomic character, but to date we have been unable to find antheridia in *A. crassicosatum*, thus its sexual condition remains unknown until antheridia are found. However, with the irregular perichaetial leaf areolation placing *A. crassicosatum* firmly in section *Phascoidea*, only comparison within that section is necessary (Snider 1975). Since the upper margins of *A. crassicosatum* are entire, *A. clavatum* I.G. Stone from Australia, *A. julaceum* Müll. Hal. from South America, and *A. julicaule* Müll. Hal. from Africa are eliminated because of their serrulate apices. Only the South African plants *A. muellerianum* Snider and *A. capense* Hornsch., have a costa as wide as 65–105 µm. *Archidium muellerianum* has papillose spores and narrowly recurved upper margins. *Archidium capense* has smooth spores like *A. crassicosatum*, but its costa is excurrent in a long awn. Neither has a costa well over 100 µm wide. All other *Archidium* in section *Phascoidea* G. Roth have narrower costae, between 30–85 µm wide (Snider 1975).

CONSERVATION IMPLICATIONS

Based on the limited number of occurrences discovered for *Archidium crassicosatum* during the past decade, we view this plant as relatively rare. Few of the occurrences are in habitats well protected on public lands. Since it is very inconspicuous during the dry season, it would be best to conduct surveys during winter and spring when the plants are actively growing and thus would be more easily noticed. In addition, the timing of winter rain is likely to influence whether a population is expressed each year. Very small soil mosses also frequently grow in mixed populations so they will need to be carefully examined microscopically since *Archidium* plants can occur as scattered individuals.

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